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ABSTRACT

Using a map for guiding travel requires: (1) skills in encoding information from a terrain and a map; (2) finding a match between the two; and (3) maintaining the match despite directional shifts from turns on a route. In order to test this analysis, 94 children between the ages of 4 and 6 used maps to locate the route to a goal through a network of paths with blind alleys. Two tasks were used as predictors of skill in map use. Laurendeau and Pinard's test of the localization of topological positions (LOTOP) supplied measures of memory encoding, correspondence, and rotation. The child copied an examiner's placements on a board when the boards were aligned or one was rotated 180 degrees. Placements were near landmarks or in an open field. The landmarks were then removed and the child had to recall their location (encoding). On the mental rotation test (MR), the child chose a rotated letter-like form to match a standard. Younger children's map errors were predicted by mental rotation skill (MR and LOTOP rotated board scores) and landmark placements. Older children's map errors were predicted by recall of landmark positions (memory encoding). (SM)

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by

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Abstract

Map use to guide travel may require skill in encoding information from a terrain and a map, finding a match between the two, and maintaning the match despite directional shifts from turns on a route. To test this analysis,94 4-to 6-yr.-olds used maps to locate the route to a goal through a network of paths with blind alleys. Two tasks were used as predictors of skill in map use. Laurendeau and Pinard's test of the localization of topological positions (LOTOP) supplied measures of memory encoding, corrspondence and rotation. The child had to copy an examiner's placements on a board when the boards were aligned or one was rotated 180 degrees. Placements were near landmarks or in the open field. The landmarks were then removed and the child had to recall their location (encoding). On the mental rotation test (MR),the child chose a rotated letter-like form to match a standard. Younger children's map errors were predicted by mental rotation skill (MR and LOTOP rotated board scores) and landmark placements. Older children's map errors were predicted by recall of landmark positions (memory encoding).

Factor, chronometric, and meta-analyses of spatial tasks suggest that spatial ability consists of a variety of skills and many spatial tasks tap more than one of them (e.g. Horan & Rosser,1984; Linn & Peterson, 1985; McGee,1979; Pellegrino & Kail,1982). Prominent among these skills are visualization, or the ability to encode and analyze a spatial pattern, and mental rotation, the ability to imagine the consequence of a spatial rotation of either the viewer or the object.

However, individual difference studies rarely include preschool samples, so we know little about the pattern of abilities in young children, the contribution of these abilities to performance on any given spatial task, and the consistency of patterns of correlations across early childhood. For example,there has been little investigation of the spatial abilities which underlie an important practical skill, wayfinding with a map. Reading a map requires integration of many skills, each of which undergoes development. First,to understand a map, the child must encode the spatial layout of the terrain the map represents. That terrain can be conceptualized in terms of its relation to the viewer, in terms of isolated landmarks, integrated networks of roads and locations, or with reference to a system of spatial coordinates (Cousins,Siegel & Maxwell,1983; Huttenlocher & Newcombe,1984; Siegel & White, 1975). Second, maps are not mirrors of the terrains they represent. Reading a map requires mastery of a symbol system and cartographic conventions. Maps vary in the degree to which they use abstract symbols and in the kinds of information they

encode about distance and elevation, so children may differ in the degree to which map information is accesible to them (e.g. Liben & Downs, 1986). Third, in order to establish a correspondence between the terrain and a map of it, the child must also learn how to interpret differences in scale, depth and perspective between the terrain and its graphic representation. Presumably, as children's comprehension of scale, depth and perspective increases, so should their ability to establish a correspondence between the map and the terrain. Using a map in wayfinding involves a fourth skill, mental rotation. Rotation may enter in at the beginning of wayfinding when a viewer must align the map with the terrain. Often preschoolers have difficulty with establishing that alignment (e.g. Bluestein & Acredolo, 1979; Presson, 1982). In addition mental rotation skills may help travellers to maintain a map-terrain correspondence despite shifts in location and direction resulting from progress on a route which changes directions and despite errors in following a marked route. Hence map usage, like other spatial tasks, requires encoding of single elements and configurations, matching ability and rotation skill.

The focus of much research on map reading has been on how each of these skills develop, since map reading provides a window for examining children's symbolic and spatial competence (e.g. Gardner,1983 ; Bluestein & Acredolo,1979; Presson,1982). The usual method of investigation has been to either manipulate the properties of maps (e.g. Scholnick, Frank ,Fein & Schwartz,1986)

or to use map performance to make inferences about the growth of separate component skills. In this study we take another approach, examining individual differences in map performance as assessed by some marker tasks (see also Liben & Downs,1986). Because there has been a great deal of emphasis on spatial encoding and visualization,and because we have just argued that map usage requires such skills, we included several different measures of encoding derived from a version of a Piagetian task (Piaget & Inhelder, 1967). The task involved two terrains placed side by side. The terrains contained roads and houses. The examiner placed a figure on one terrain and asked the child to place a similar figure on the identical spot on the child's terrain. Like map reading, this task requires the child to establish a correspondence between one spatial array and another, but unlike a map task, the two arrays are identical ,so the child need not make any transformations of scale or translations of symbols. One encoding measure gauged the child's ability to think in terms of single locations. The figure was placed near a landmark. A second task required the child to reproduce locations, but there was no adjacent landmark so the child had to use the entire configuration of the terrain to make the placement. In a third measure, the landmarks were removed from both boards and the child had to replace them. To do so the child had to remember the configuration of the entire board. Two measures of mental rotation were also included. One was derived from the Piagetian task, reproduction of locations when the examiner's

and the child's board were not aligned. The second involved rotation of single figures, rather than an array.

We examined two models of performance. The first suggests that there is age invariance in the skills required to use maps. In the period from four to six and a half years, children's success is based upon coordinating both visualization and rotation skills. The second model presumes there are developmental differences. We know, for example, that there are different strategies of performing mental rotation tasks(Cooper,1982). Perhaps there are also different strategies for using maps in way finding which reflect differences in how the child conceptualizes the terrain and the task itself. At first the key skill for wayfinding using a map is the one we use when wayfinding when we lack a map. We must maintain orientation from the place of departure despite rotation. Young children may also conceptualize the terrain in terms of isolated landmarks (Siegel & White,1975). Hence skill in mental rotation and landmark encoding are the best predictors of map usage. Later in development, the child may have be more aware of the utility of a map and skill in map reading may vary with the extent to which the child can retain information derived from glances at map and from the child's ability to conceptualize the map as a configuration of spatial information which corresponds to the landscape (Frank, 1986). Thus complex encoding and recall skills would be more predictive of performance than ability to imagine spatial rotations.

In summary, we examined map usage in two groups of children,

four-year-olds and five to six year-olds. The children's ability to encode a terrain and remember it were also assessed as well as their ability to deal with the consequences of mental rotation.

Method

Participants:

The sample consistud of 94 children attending three schools in the same suburban area, a University nursery school and two suburban day care centers. The population was middle class and of diverse ethnicities. There were 48 males and 46 females,whom we divided into two age groups. The younger group contained 48 children between 48 and 63 months of age (M = 57 mos.) and the older group consisted of 46 children between 64 and 79 mos (M = 70 mos.). Within each age, there were approximately the same number of boys as girls.

Procedures:

Predictors of route map performance were derived from two tasks. Those tasks and the map task are described in turn.

Localization of Topographical Positions(LOTOP). The LOTOP task was originally developed by Piaget and Inhelder (1967) to test steps towards the emergence of an objective spatial reference system used to locate objects in a terrain. According to Piaget, children rely at first on a self-reference system in which the location of objects is coded with reference to the child's viewing perspective. The first step away from this subjective perspective is the encoding of objects with

reference to landmarks and then in open field positions where locations are defined with reference to the layout of the entire space and not in terms of adjancy to particular objects within it. In time, locations of objects can be described independently of the viewer's position in space so that objects can be located even when the position of the terrain is rotated. Our procedures and scoring criteria are derived from a standardized version of the task reported by Laurendeau and Pinard (1970).

The task was presented on two identical posterboard terrains (35 X 47 cm.). Each terrain was divided by an intersecting road and track into four unequal quadrants drawn on the posterboard. See Figure 1. Each terrain contained five toy houses of assorted sizes and colors, scattered at three locations. The child and examiner sat on opposite sides of the testing table midway between the two boards. At first the two boards were aligned. The examiner placed a toy figure on the board to the child's right and the child had to copy its placement on the other board. There were 12 placements, 7 near landmarks (A-G), and 5 (H-L) in open field positions. These were administered in a fixed order as in the original Laurendeau and Pinard procedure. Then the examiner's board was rotated 180 degrees and the child was asked to reproduce the same 12 placements.

Insert Figure 1 about here

Upon completion of the 24 placements, the three-dimensional

landmarks were removed from both boards. One set was given to the child who was asked to return them to their original locations on the child's board (the unrotated one).

In order to facilitate accuracy of scoring,the test boards were covered with clear plastic sheets marked by small, barely noticeable slits varying in size. Larger slits marked the locations of three-dimensional landmarks and the boundaries within which a response would be considered correct, a circle with a 2-3 cm radius around the target location. Smaller slits acted as foils. From these placements, four scores were derived: (1)LPU-the total number of correct placements out of 12 on the unrotated board; (2) LPR-the total number of correct placements out of 12 on the rotated board ; (3)LPL-the total number of correct placements near landmarks regardless of board position from a maximum of 14, and (4) LPOF-the total number of correct open field placements regardless of board alignment out of a total of 10. The second pair of scores is merely a recategorization of the first pair of scores so that the two sets (1 and 2 vs. 3 and 4) were never used in the same regression analysis. LPL scores represent reliance on landmark features or a topological framework to judge locations. LPOF represents the ability to code locations with reference to the entire board configuration; LPU taps the ability to establish a correspondence between arrays while LPR taps the ability to transpose an array.

In addition, a memory encoding score was derived from the child's recall of the location of the landmarks. There were

three clusters of landmarks. Each cluster replacement received a score of one point for accuracy of quadrant location,one point for accuracy of alignment of the building, and one point for placement within 3 cm. of the exact location of the original landmark location.

Mental Rotation Test. The mental rotation test was derived from Thurstone's (1958) Primary Mental Abilities Battery. It consisted of 17 items in which the child was to choose one of three comparison figures to match an assymmetrical 4 cm tall letter-like form. See Figure 2. One choice was a rotation of the standard figure and the two foils were mirror images of the standard rotated to the same degree as the correct choice to the right and to the left. The first 12 trials consisted on three presentations each of figures with rotations of 30,45,90, 125, 160, and 180 degrees to the left or right. During those trials,the child was given a carboard cut out shape painted black on its top and red on the underside. The child was asked to match the cutout to the standard figure, to pretend that the figure was rotated, and then choose the figure that would result from the rotation. The child then verified the correctness of the choice by rotating the cardboard shape on the chosen figure, and if the choice was in error, finding the correct match. Verification was discontinued in the last five trials which consisted of a new set of forms with rotations of 30, 45, 90, 125, and 160 degrees. Performance on the first and second parts of the test was correlated (r=.53) so the MRT score was

the total number of initial correct choices.

Insert Figures 2 and 3 about here

<u>Map Task.</u> The map task required the child to use route maps to take a toy to certain locations. The children worked on three terrains,two during an introductory task, and one during the experimental task. Each resembled the kind of material usually used in nursery school constructions of model towns. We used an small,artificial landscape in order to control and equate features of the pathways. The terrain in the experimental task was a 106.7 x 182.9 cm. green formboard depicting four networks of 3.8 cm. wide yellow paths and two blue rivers separating the path networks from one another (see Figure 3). Every path network contained equally spaced forks in which one branch led onward to the next but the other branches ended at an identical tan 3.8 X 3.8 X 3.8 cm block house. An animal sticker was pasted beneath one house at the last (goal) fork.

The four path networks differed in the number of forks (3 or 4) they contained and the total number of branches across all forks (8 or 12). The 3-12 network had 3 forks each with 4 branches; the 3-8 path network also had 3 forks but only 8 branches; the 4-12 path network had 4 forks with 12 branches distributed among them and the 4-8 network had 4 forks, each with 2 branches, for a total of 8. The number of required left and right turns, curved and straight forks and goals to the

left and right of the starting point were counterbalanced across the paths. The paths on the introductory task were drawn on smaller boards and contained one or two two-branched forks.

Each path network was represented by a black and white 1:6 scale map depicting the entire path network with the correct route to the goal house marked by a series of black arrows connected by a yellow line. The only house shown on the map was the goal house which was symbolized by an animal sticker identical to the one pasted beneath the goal house on the actual terrain. Hence the map differed in scale, dimensionality, detail and symbolization from the actual terrain.

The child began the task with an introduction to Clyde, a toy caterpillar, who wished to visit friends who lived on one of the small terrains. The child was told that a map would show the child how to find his friends. The child then progressed through a set of routines that was used on each subsequent route. The child was shown the map and asked to trace the route to the friend with a finger. Next the child was taken to the start of the path on the terrain. The map was aligned with the path network and placed at the child's right as the child faced the terrain. The map remained there available for consultation. The child was then given Clyde and asked to take him along the path to the friend's house. Upon reaching the house, the child was asked to check beneath it for the presence of the appropriate sticker. If the wrong house was chosen, the child was encouraged to consult the map and continue the search. On the first trial

alone, the route and direction of turns on the map were described during the child's travels. Then the child worked unaided on two more introductory paths before moving to the larger terrain. Here the child learned that Clyde's friends had arranged a birthday surprise for him. There were four pieces of a puzzle that, when assembled, would identify the prize. The child was to help Clyde find the pieces, each located at a different friend's home on a different path network. At the end, the puzzle depicting a hot air baloon was assembled and the child was allowed to take Clyde for a ride in a miniature balloon.

The task was administered by one experimenter and a second served as an observer recording Clyde's movements on a duplicate map. In a separate reliability study two observers simultaneously recorded eight children on the same task. There was 95 % agreement on the record of child movement along each path segment.

An error was defined as taking the wrong direction through a fork by either choosing the wrong branch or backtracking to an earlier fork. Errors were summed across all four terrains.

Results and Discussion

Age differences in level of performance. Table 1 presents the scores for the six predictor variables and map performance. A Manova comparing the scores of the two age groups on map, mental rotation, memory encoding scoresand LOTOP placements divided by rotated and unrotated boards revealed significantly better performance for the older group in general, $F(5,86)=7.32$, $p<.001$. Univariate tests of each dependent variable also yielded

significant F ratios(df= 1,90, p <.02) showing better performance by the older children on each measure: Map errors F= 18.99, Mental Rotation, F= 29.69, LPU,F= 11.27, LPR F= 5.92, Memory encoding= 11.26. In a second Manova in which the landmark-open categorization was substituted for rotated and unrotated boards,older children also performed significantly better, Multivariate F (5,86)=7.14, p <.001 and the two new dependent variables produced significant univariate F-ratios for age, F (1, 90)= 8.14 for landmark placements, and F (1,90)= 9.35, p <.005. In similar tests assessing gender differences, one univariate test showed a significant difference favoring males, landmark placements F (1,90)= 4.16, p <.05. When tests were done within each age group,the sex differences were localized within the younger group.

Patterns of performance. Because age contributes to each task, subsequent analyses were done with age partialled out. Table 2 presents task correlations within the two age groups with age and sex partialled out. We then estimated the scores for each task by partialling out age effects and did multiple regression analyses on the residuals. Table 3 shows the results of multiple regression analyses of map errors for the entire group and for each age. This table includes standardized coefficients which index the degree to which each variable uniquely accounted for map errors. Two regression analyses were computed at each age. In one, the predictors of map errors were mental rotation, LOTOP scores divided by board alignment (LPU, LPR), and encoding. The

adjusted R^2 for younger children was .41 Three variables made significant and unique contributions to performance, mental rotation and LP unrotated and rotated placements. When the same regression analysis was done on performance in the older group,the multiple R^2 was lower (.23)and an entirely different variable,memory encoding, was the sole significant unique predictor. In a second set of analyses, the LOTOP scores were instead divided by landmark versus open field placements. The adjusted R^2 for the younger group was .43 and two variables made unique and significant contributions to performance, landmark placements and as before, mental rotation. In contrast, the R^2 was lower for the older group .24, and as before, the only significant predictor was mental encoding although open field placements and mental rotation were contributing somewhat to performance ($p < .10$). Thus the two groups of children were drawing on different abilities to do the route map task. In the younger sample the key correlates of map reading ability are skill in mental rotation of a single figure and landmark knowledge (see also Liben & Downs, 1986). The partial correlations of Table 2 suggest that for younger children the ability to rotate a single figure is not related to the ability to imagine placements when a whole terrain is rotated. In contrast in the older group mental rotation of a single figure plays a lesser role. It does so for two reasons. First, mental rotation is related to others of the predictors so that it no longer contributes as much unique variance. The ability to imagine the consequences of rotating a single figure is related to dealing

with the consequences of rotating an entire landscape and to skill in using landmarks to make judgments of location. Secondly, the older child seems to be drawing on a set of abilities which will solve the task in a different way.

How does one handle a map task? One way is by trial and error search of the terrain with minimal reference to a map. If there are errors, it becomes important to maintain one's orientation relative to the start position in order to avoid backtracking. Mental rotation skills are important in maintaining that orientation. Alternatively the individual can begin by encoding an image of the map route which is consulted when choosing branches at an intersection. The more one encodes in the original image, the less the map needs to be consulted in making a choice. Hence the adequacy of the initial encoding of the map guides the wayfinding process.

In summary these data suggest that multiple spatial skills enter into map reading performance when the task is finding one's way on a route. Moreover those skills shift with age. The shift does not occur because older children reach a ceiling on the map task or on the marker tasks. Rather the the task is conceptualized differently in several resepcts. The child may be encoding the map and terrain as a coherent whole rather than as isolated bits of information and the child may be using the map differently in guiding search and repairing errors. Moreover metal rotation skills may be less task specific.

However, the data raise two related,intriguing questions.

What covaries with age and what accounts for the unexplained variance? What other skills might be important? One is whether the child understands the advantage of using a map. Several of our younger children appeared to be searching directly, rather than consulting the material. Liben and Downs (1986) suggest that operativity or the logical framework which one employs might be implicated. Certain nonspatial skills involving quantification and symbolization might be implicated. Certainly skills in analyzing a path, and ordering its parts would facilitate wayfinding and map consultation (e.g. Scholnick et al.,1986). Frank (1986) implicates metacognitive skills used to signal when it is generally necessary to consult a map (at choice points) and when the child, in particular needs, more information.

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Table 1. Age Differences in Performance on the Map and Spatial Tasks

	Younger Group		Older Group		Maximum Score
	Mean	S.D.	Mean	S.D.	
Map Errors	13.8	8.0	7.7	6.1	40
MRT Correct	7.1	2.2	10.3	3.2	17
LOTOP Correct					
LPUnrotated	7.6	2.2	9.0	1.8	12
LPRotated	3.5	2.0	4.7	2.5	12
LPLandmark	8.1	2.0	9.6	2.1	14
LPOpenField	3.0	1.9	4.2	2.0	10
Memory Encoding	5.1	2.3	6.6	1.9	9

Table 2. Task Intercorrelations (with age and sex effects partialled out) .

YOUNGER CHILDREN

	MRT	ENC	LPU	LPR	LPLA	LPOF
MAP	-.48*	-.12	-.45*	-.34	-.49*	-.29
MRT		-.01	+.11	-.06	+.02	+.04
ENC			+.26	+.19	+.14	+.33
LPU				+.34	+.63*	+.78*
LPR					+.79*	+.49*
LPLA						+.35

OLDER CHILDREN

	MRT	ENC	LPU	LPR	LPLA	LPOF
MAP	-.311	-.403	-.35	-.26	-.33	-.29
MRT		+.07	+.23	+.47*	+.47*	+.28
ENC			+.21	+.12	+.35	-.06
LPU				+.29	+.54*	+.70*
LPR					+.83*	+.63*
LPLA						+.46*

* $p < .05$

Table 3. Predictors of Map Performance When Age is Partialled Out from Each Score (Standardized Coefficients)

Variable	Total Group (N=94)	Young (N- 48)	Old (N= 46)
LPU	-.31*	-.33*	-.21
LPR	-.11	-.29*	-.06
Encoding	-.14	+.01	-.34*
MRT	-.29*	-.46*	-.21
R^2	.27	.41	.23
LPL	-.27*	-.46*	-.04
LPOF	-.13	-.13	-.26
Encoding	-.14	-.02	-.42*
MRT	-.27*	-.46*	-.24
R^2	.25	.43	.24

Figure Captions

Fig.1 Score sheet for the LOTOP Task

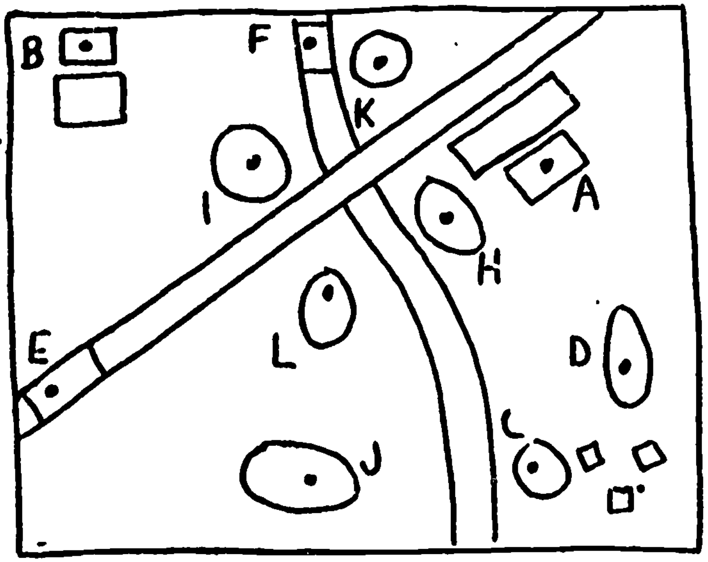
Fig.2 Score sheet for the Mental Rotation Task

Fig.3 A Schematic Drawing of the Terrain showing the location of just the Goal House and start of the Path

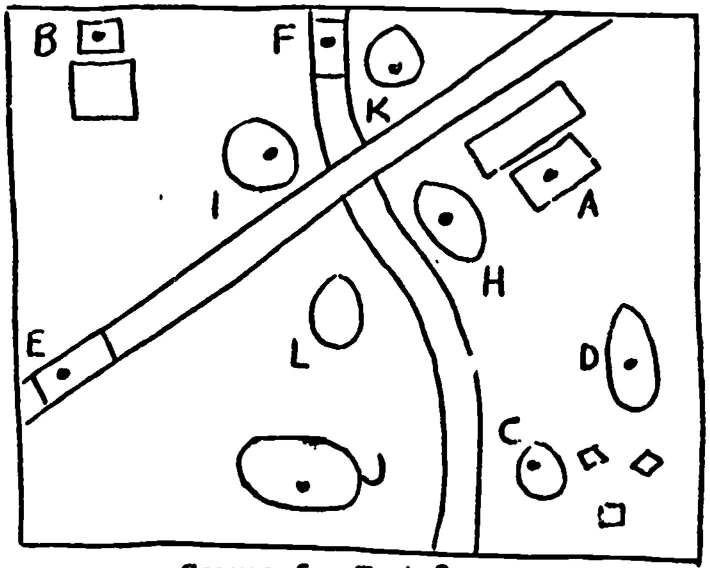
I.D. Number:______________ Birthdate:_____________ Test Number:_______ Test adminisrator:_____________

Name:___________________________ Sex:_________ Date administered:______________________________

Laurendeau and Pinard Localization of Topographical Positions



Scores for Test 1



Scores for Test 2

Analysis of scores: Circle problem if correct. Underline problem if incorrect.

Test 1: Sequence of problems: A, B, L, C, F, H, E, D, J, K, G, and I (Rotated 180 degrees)

Test 2: Sequence of problems: B, D, G, A, L, E, K, I, J, H, C, and F

Univac sequence:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70

METAL ROTATIONS TEST -- SCORE SHEET

I. D. No. ____________ Time at start ____________

Sex ____________ Time at finish ____________

Age ______ Birthdate ____________ Examiner ____________

	Position One	Position Two	Position Three	Comments
Trial 1				
Level 1 (slide)				
Level 2 (30° R)				
Level 3 (30° L)				
Level 4 (45° R)				
Trial 2				
Level 1 (45° R)				
Level 2 (90° L)				
Level 3 (90° R)				
Level 4 (125° L)				
Trial 3				
Level 1 (125°L)				
Level 2 (160° R)				
Level 3 (160° L)				
Level 4 (180°)				

Test 1				
Test 2				
Test 3				
Test 4				
Test 5				

Score: Trials ____ out of 12; Test ____ out of 5; Total